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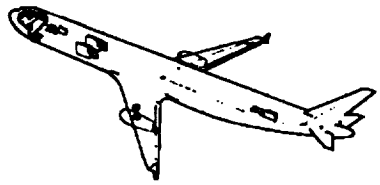
HIGHLY-RELIABLE FLY-BY-LIGHT/POWER-BY-WIRE TECHNOLOGY



Felix L. Pitts

NASA Langley Research Center

Workshop on Guidance, Navigation, Controls, and Dynamics for Atmospheric Flight

March 18, 1993

FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

OUTLINE

PROGRAM OVERVIEW
- Background
- Goals/Objectives
- Approach / Milestones
- Deliverables

FY 92 PROGRAM ACCOMPLISHMENTS
- Workshop Summary
- Optical Sensors
- EME

FY 93 Plans

ELECTROMAGNETIC MODELING VIDEO

PROGRAM OVERVIEW

PROGRAM HISTORY

- Suggested By Industry In Civil Aeronautics Technology Development and Validation Plan
- NASA AAC Reviews: 11/88-LaRC; 1/90-ARC; 11/91-LeRC
- Non-Advocate Review 8/90 @ NASA HQ
- Draft Working Plan 7/91; Draft Program Plan 9/91
- Requirements Workshop @ LaRC 3/92
- NASA Red/Blue Team: Circa 1992

- APPROXIMATE CURRENT BUDGET (NET $M)

FY 93	FY94	FY95	FY96	FY97	FY98
4	6	7	8	9	10

FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

FBL/PBW

WHAT IS IT?

- REPLACEMENT OF ELECTRONIC DATA TRANSMISSION, MECHANICAL CONTROL LINKAGES, AND ELECTRONIC SENSORS WITH OPTICAL COMPONENTS AND SUBSYSTEMS
- ELIMINATION OF HYDRAULICS, VARIABLE ENGINE BLEED AIR, AND THE CONSTANT SPEED DRIVE FOR POWER GENERATION THROUGH ADVANCES IN AEROSPACE POWER SYSTEM TECHNOLOGY
  - ELECTRONIC MOTOR CONTROLLERS
  - POWER SYSTEM DISTRIBUTION AND CONTROL

BENEFITS

- CIRCUMVENT EMI CONCERNS IN APPLYING DIGITAL CONTROL
  - Intrinsic EMI Immunity and Lifetime Immunity to Signal EMI of Optics
  - Simplify Certification
- ELIMINATE HYDRAULICS, ENGINE BLEED AIR, VSCF DRIVE
- WEIGHT AND VOLUME REDUCTION

ENHANCE DIGITAL CONTROL ACCEPTANCE

FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

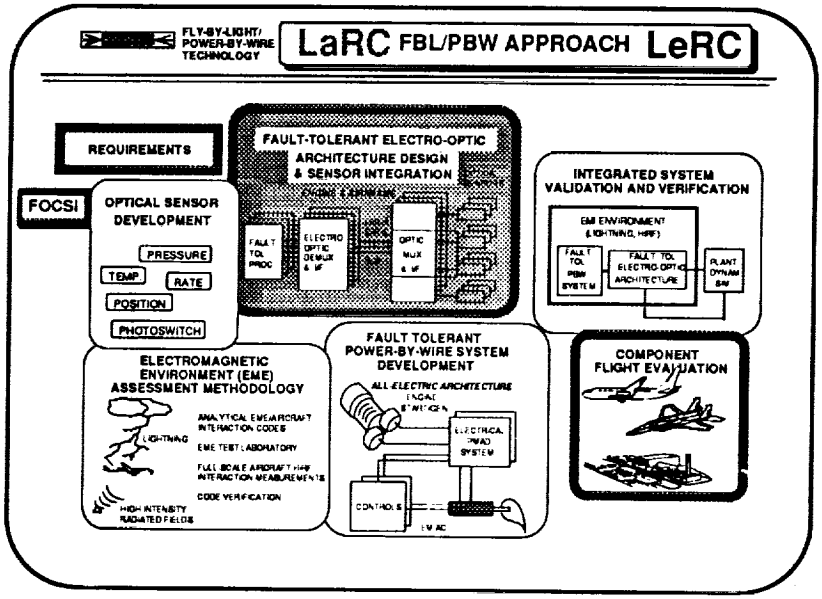
FBL/PBW WORK BREAKDOWN STRUCTURE

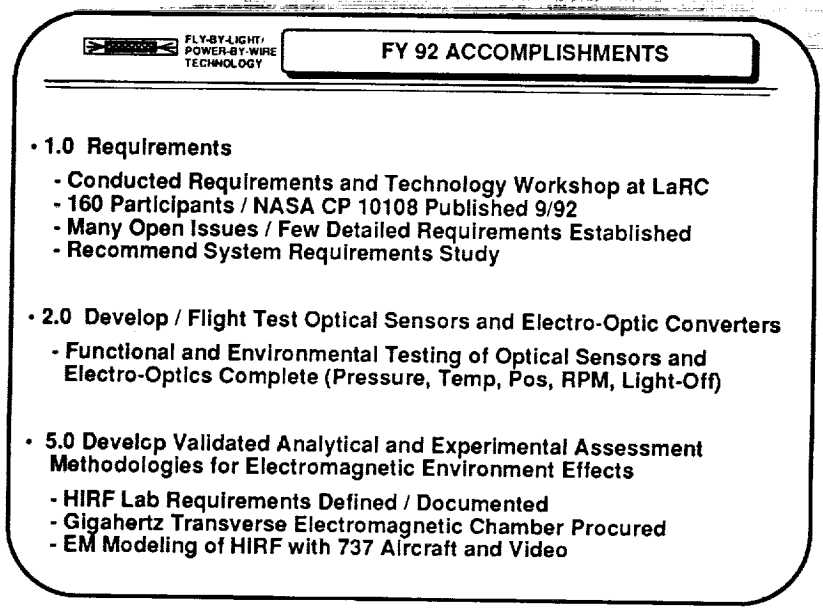
HIGHLY RELIABLE FLY-BY-LIGHT/POWER-BY-WIRE SYSTEMS TECHNOLOGY

GOAL: Develop the Technology Base for Confident Application of Integrated FBL/PBW Systems to Transport Aircraft

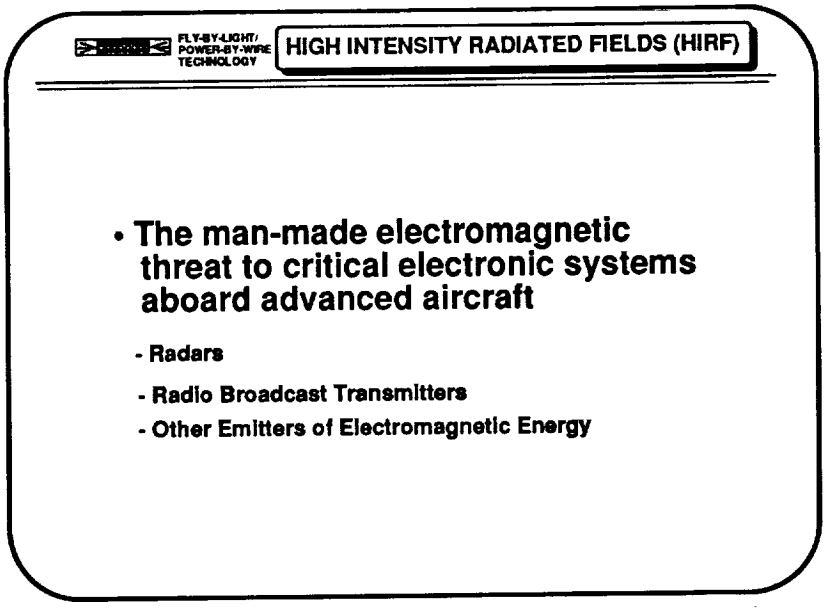
OBJECTIVES:

- 1.0 Requirements and Preliminary Design
- 2.0 Develop and Flight Test Optical Sensors and Electro-Optical Converters
- 3.0 Develop and Ground Test a Power Management and Distribution System and Flight Test an Electrical Actuator
- 4.0 Demonstrate Architecture Design and Validation Appropriate for Certification of FBL/PBW Systems
- 5.0 Develop Validated Analytical and Experimental Assessment Methodologies for Electromagnetic Environment Effects
- 6.0 Demonstrate End-to-End FBL/PBW Systems in Ground Tests and Partial Flight Test


FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY
LaRC FBL/PBW APPROACH LeRC
REQUIREMENTS
FOCSI
OPTICAL SENSOR DEVELOPMENT
PRESSURE
TEMP
RATE
POSITION
PHOTOSWITCH
FAULT-TOLERANT ELECTRO-OPTIC ARCHITECTURE DESIGN & SENSOR INTEGRATION
INTEGRATED SYSTEM VALIDATION AND VERIFICATION
ELECTROMAGNETIC ENVIRONMENT (EME) ASSESSMENT METHODOLOGY
FAULT TOLERANT POWER-BY-WIRE SYSTEM DEVELOPMENT
COMPONENT FLIGHT EVALUATION


FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY
FY 92 ACCOMPLISHMENTS
• 1.0 Requirements
- Conducted Requirements and Technology Workshop at LaRC
- 160 Participants / NASA CP 10108 Published 9/92
- Many Open Issues / Few Detailed Requirements Established
- Recommend System Requirements Study
• 2.0 Develop / Flight Test Optical Sensors and Electro-Optic Converters
- Functional and Environmental Testing of Optical Sensors and Electro-Optics Complete (Pressure, Temp, Pos, RPM, Light-Off)
• 5.0 Develop Validated Analytical and Experimental Assessment Methodologies for Electromagnetic Environment Effects
- HIRF Lab Requirements Defined / Documented
- Gigahertz Transverse Electromagnetic Chamber Procured
- EM Modeling of HIRF with 737 Aircraft and Video

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS SUMMARY



FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

HIRF THREAT to ADVANCED AIRCRAFT

- **Composite Structures**
  - Less Shielding than All Metal
- **Flight-Critical Controls**
  - Higher Reliability Requirements than Non-Critical Controls
- **Digital Control Systems**
  - More Sensitive to Transients than Analog
  - Can Cause Correct Operation without Component Damage

Upsets Cannot Be Tolerated
In Advanced Aircraft Systems

FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

HIRF OVERVIEW

- FAA Commissioned SAE-AE-4R Committee 12/88
  - Advisory Circular and Users Manual for Hazards of Electromagnetic Radiation to Aircraft
- Chair: Stan Schneider, Boeing Military Airplane Co.
  Secretary: Noel Sargent, LeRC
  -Three Sub-Committees
  Environment (Chair: Ron Rodgers, ALPA)
  Advisory Circular (Chair: Chris Kendall, CKC Consultants)
  Users Manual (Chair: Fred Heather, Patuxent River NAS)
- Status: Final Meeting 1/92
  - SAE Report Spring 1992
- Problems
  - How to Use and Apply, How to Treat Critical versus Essential Systems
  - Need Lab/Bench Tests
- Research Opportunities
  - Modeling and Test Techniques

FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

DIGITAL SYSTEM UPSET

- Functional Error Mode
  - System/Subsystem Level
  - Caused by Electrical Transient
    - Lightning
    - HIRF
    - NEMP
    - SEU / Inter-Galactic Particles
  - No Component Damage
- Corrective Action
  - Reset/Reload Software
  - Internal Recovery Mechanism
- No Standard Guidelines/Criteria
  - Upset Detection
  - Designing Reliable Upset Recovery Mechanisms
  - Performing Tests/Analyses for Upset Susceptibility/Reliability

FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

CURRENT EME ACTIVITIES

- Lawrence Livermore Transport Aircraft Internal EME

- LaRC Lab HIRF Assessment
  - AIRLAB HIRF Test Facility
  - Bendix Quad Flight Control System (Loan)

FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

INTERNAL EME

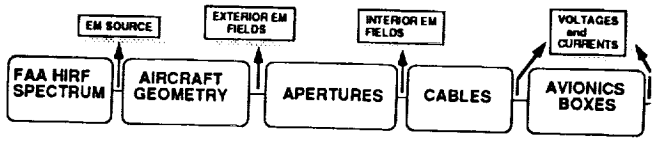
OBJECTIVE:

Develop a baseline internal Electromagnetic Environment (EME) assessment methodology for the proposed Fly-By-Light/Power-By-Wire augmentation

APPROACH:

Apply Lawrence Livermore National Laboratory (LLNL) weapons system High Power Microwave EME assessment technology to transport aircraft

- Model EM interactions using LLNL codes
- Validate model with experimental data

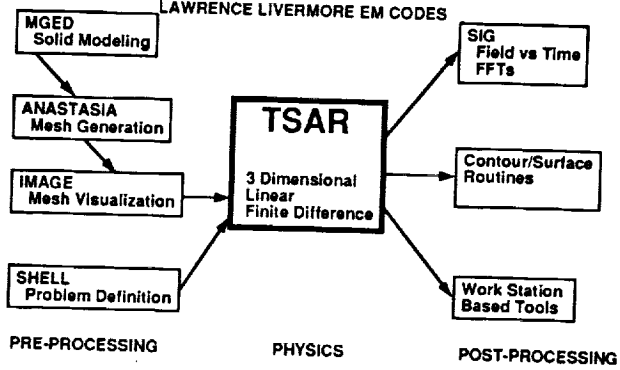


FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

EM MODELING

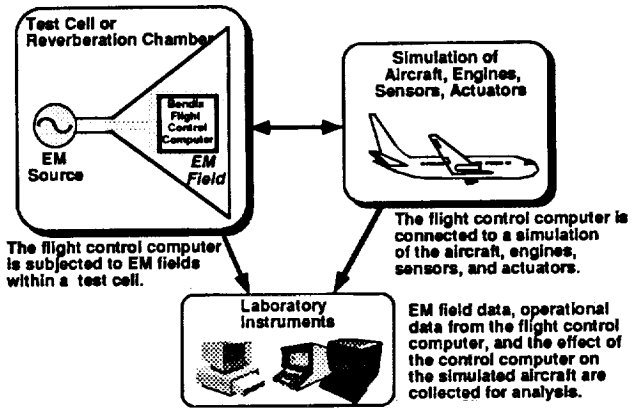
TEMPORAL SCATTERING & RESPONSE EM MODELING

LAWRENCE LIVERMORE EM CODES



FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

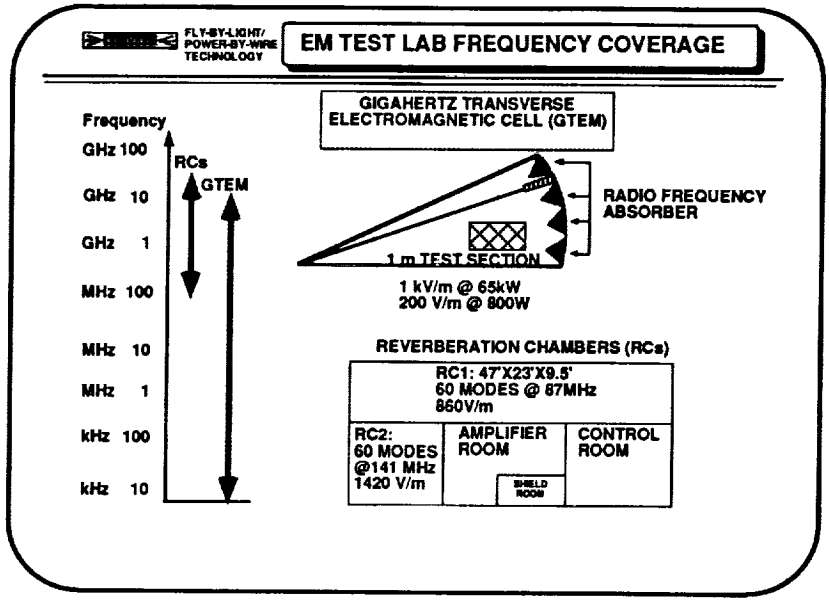
HIRF LABORATORY



FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

AIRLAB HIRF EM TEST LAB

- GIGAHERTZ TRANSVERSE ELECTROMAGNETIC CELL (GTEM)
  - High Field Levels (1 kV/m CW) Testing DC to 1 GHz
  - Moderate Field Levels (<400 V/m CW) Testing DC to 10 GHz
  - High Field Levels Pulse Testing (40 kV/m) from DC to 10 GHz
  - Instrument Calibration Capability DC and 10 GHz
- REVERBERATION CHAMBERS
  - Low Power (0.9kW vs 65kW @ 1kV/m, 1GHz for GTEM)
  - No Test Article Re-orientation
  - RC1 Coverage >87MHz, RC2 Coverage >141MHz
  - Random Field Polarization and Large Number of Modes Necessitate Separate Sensor Calibration Facility such as GTEM


FLY-BY-LIGHT/
POWER-BY-WIRE
TECHNOLOGY
EM TEST LAB FREQUENCY COVERAGE
Frequency
GHz 100
GHz 10
GHz 1
MHz 100
MHz 10
MHz 1
kHz 100
kHz 10
RCs
GTEM
GIGAHERTZ TRANSVERSE
ELECTROMAGNETIC CELL (GTEM)
RADIO FREQUENCY
ABSORBER
1 m TEST SECTION
1 kV/m @ 65kW
200 V/m @ 800W
REVERBERATION CHAMBERS (RCs)
RC1: 47'X23'X9.5'
60 MODES @ 87MHz
860V/m
RC2:
60 MODES
@141 MHz
1420 V/m
AMPLIFIER
ROOM
SHIELD
ROOM
CONTROL
ROOM

FY 93 PLANS

FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

FY 93 PLANS

- 1.0 Requirements
  - Integrated Requirements Analysis and Preliminary Design Studies
- 2.0 Develop and Flight Test Optical Sensors and Electro-Optical Converters
  - Flight Test FOCSI Optical Sensors on F-18 SRA
  - Competitive Procurement of Task Assignment Contract
- 3.0 Develop and Ground Test a Power Management and Distribution System and Flight Test an Electrical Actuator
  - Competitive Procurement of Task Assignment Contract
- 4.0 Demonstrate Architecture Design and Validation Appropriate for Certification of FBL/PBW Systems (Prelim Design under 1.0)
- 5.0 Develop Validated Analytical and Experimental Assessment Methodologies for Electromagnetic Environment Effects
  - Validate Code with ATOPS 737 Aircraft, HIRF 400Hz Protection Study
  - Build HIRF Lab

FLY-BY-LIGHT/ POWER-BY-WIRE TECHNOLOGY

Integrated Requirements Analysis and Preliminary Design Studies

- REQUIREMENTS GENERATION
  - Aircraft Specification
  - Most Aircraft Systems-Priority to Flight Critical Systems
  - Sensors, Actuators, Computation, Power, Pneumatics
- TECHNOLOGY ASSESSMENTS
  - Photonics, Sensor Encoding, Various Electrical Actuators, Power, Pneumatics,

    Data Comm, Systems Technologies/Integration
- ARCHITECTURE TRADES
  - Centralized/Distributed, Dumb/Smart Actuators, Integrated/Stand Alone Power Mgt, Integration/Separation of Critical and Non-Critical Tasks
- SYSTEM DESIGN and ANALYSIS
  - Preliminary Design of Candidate Architecture
  - Recommend Flight Configuration for 1996 and 1998 Demo